Performance Study of an Amorphous-Silicon Flat Panel Detector for Fast Neutron Imaging of Nuclear Waste

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Introduction

For non destructive characterization of nuclear waste detailed information about massive and dense structural components are needed from radiography to improve analytical results.

Setup

Detector Design

- Commercial X-Ray detector (PerkinElmer)
- Active area: 40 x 40 cm²
- Segmentation: 1024 x 1024 pixels

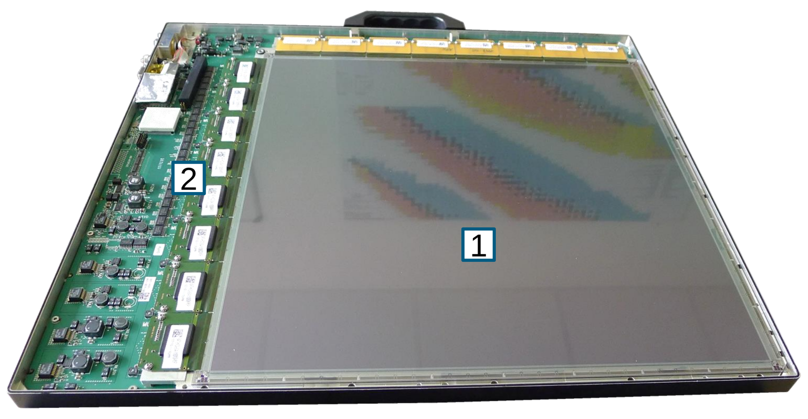


Fig. 1: Opened detector without scintillator. 1 Active area made from aSi. 2 Electronics

Scintillator

- General purpose plastic scintillator
- EJ-260 Eljen Technology
- Thickness: 3 mm

Fig. 2: General purpose plastic scintillator used for fast neutron detection via recoil protons.

Neutron generator

- Commercial generator Genie16GT (Sodern)
- D-T fusion for 14 MeV neutrons
- Flux determination with monitoring foils (Al, Au)
- Distance source to foils: 30 cm
- Activity measurement with HPGe detector
- Fast neutron source strength:

$$Q_{fast} = 15.7 \pm 2.6 \cdot 10^{7}\ \text{n/s}$$

Reaction	A in Bq	Φ in cm⁻²s⁻¹	Q in s⁻¹
$^{197}Au(n,\gamma)^{198}Au$	2.48	$28.1 \cdot 10^{1}$	$3.2 \cdot 10^{6}$
$^{197}Au(n,2n)^{196}Au$	0.10	$12.2 \cdot 10^{3}$	$1.4 \cdot 10^{8}$
$^{27}Al(n,\alpha)^{24}Na$	0.38	$15.5 \cdot 10^{3}$	$1.7 \cdot 10^{8}$

Tab. 1: Analysed reactions with corresponding activities, neutron fluxes and source strengths.

Experiment

- Neutron generator within 10-20 cm PE shield
- Distance source to detector: 42 cm
- Samples on lift table

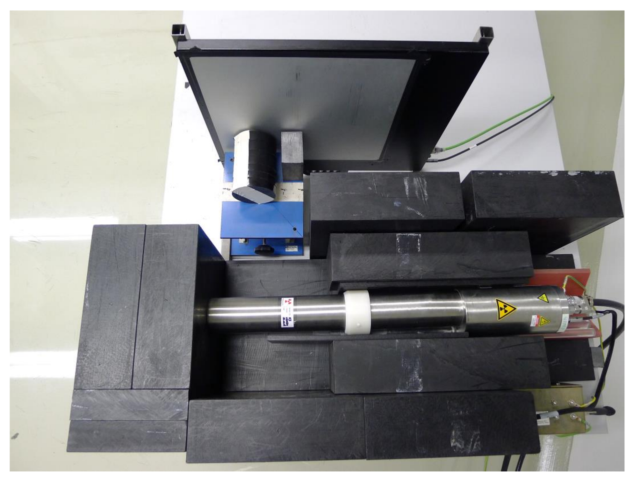


Fig. 3: Experimental setup with samples of PE and lead. Shielding lid is removed.

Image Analysis

Setup

- Pb brick and PE cylinder
- Distance source detector: 42 cm
- Average of 450 frames, each 2 s

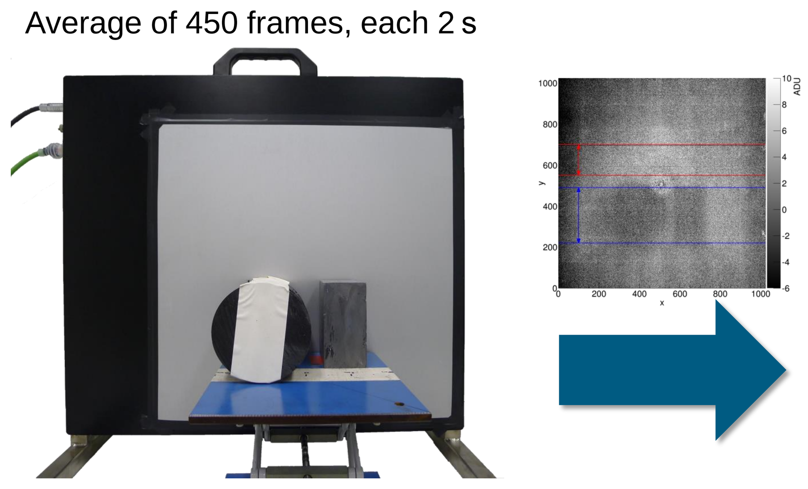


Fig. 4: Photograph of the setup for the following radiographs.

Smooth

- Profiles of areas with and without objects
- Set outliners to the average of the surrounded pixels

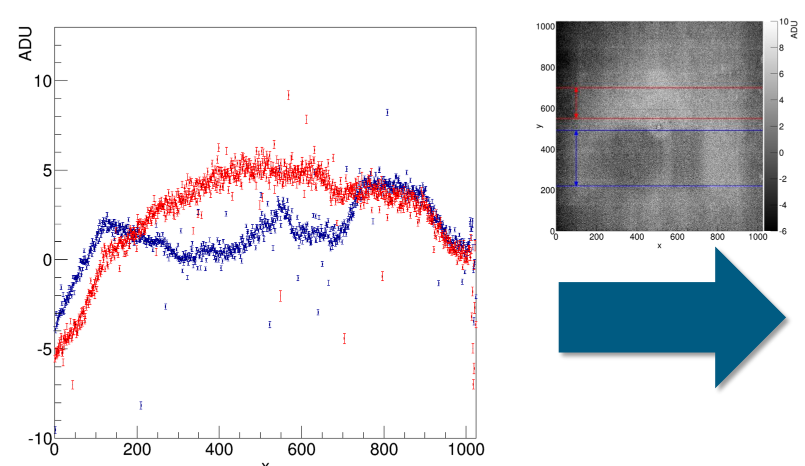


Fig. 5: Profiles of the area without object (red) and including the object (blue).

Profile Correction

- Set area without objects as background

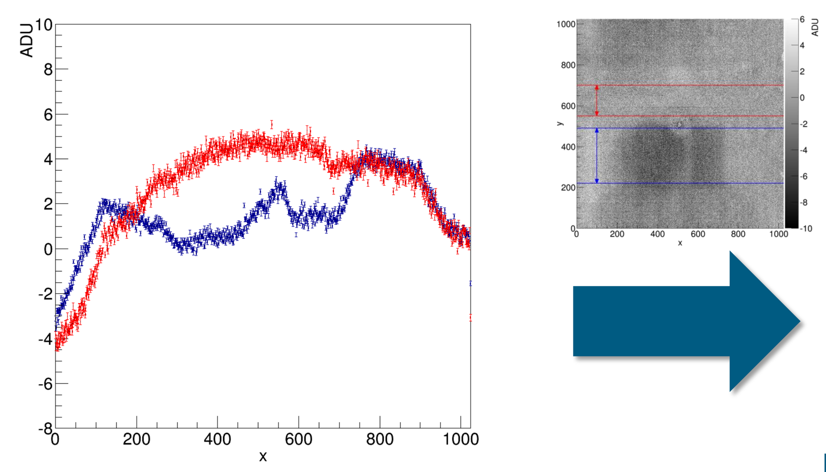
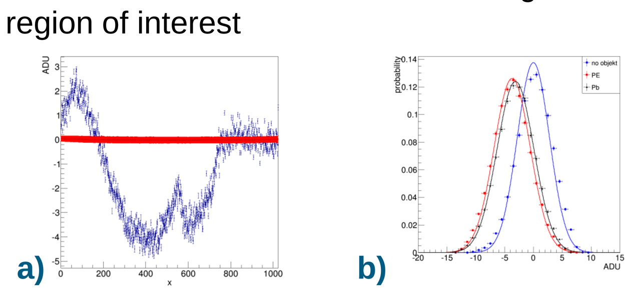
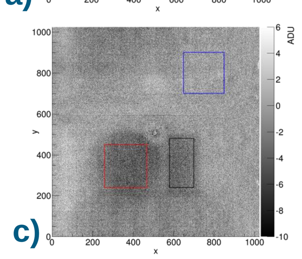


Fig. 6: Profiles of the smoothed radiograph.

Signal Analysis

- Fit Gaussian distribution to histogram from region of interest





Area	μ in ADU
No obj.	-0.01(2)
PE	-3.68(2)
Pb	-3.11(2)

Fig. 7: a) Profiles of the corrected radiograph. b) histogram of the region of interest from areas seen in c). d) Mean values of the Gaussian fits.

Results

Calibration

- Radiographs of well known test samples
  - Size: 5 x 8 x 10 cm³
  - Al, C, Fe, Pb, W, concrete, PE
- PE as reference
- Combination of two samples
- Analysis as shown before

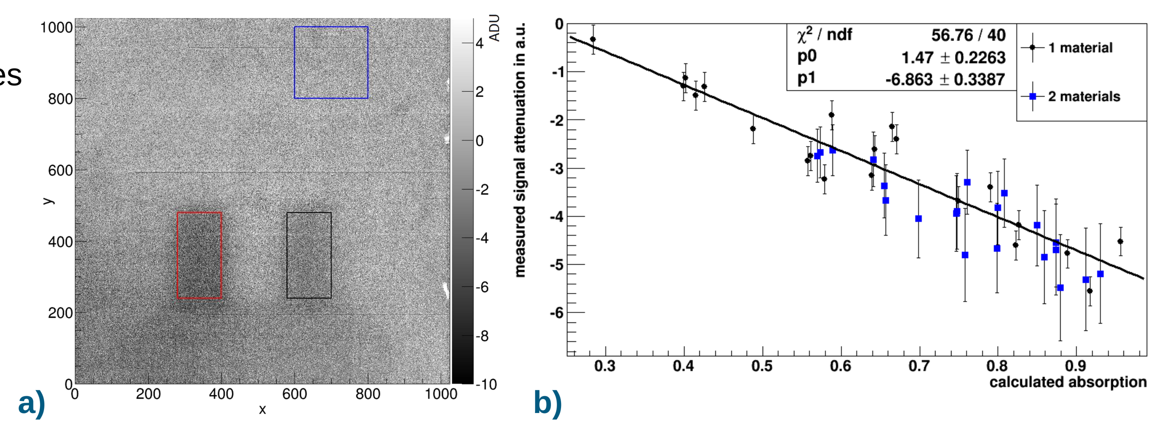


Fig. 9: a) Radiograph of Pb (red) and PE (black) sample. b) correlation between measured and calculated signal attenuation.

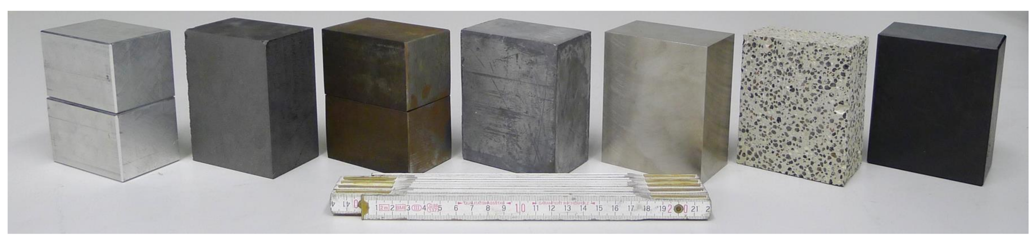
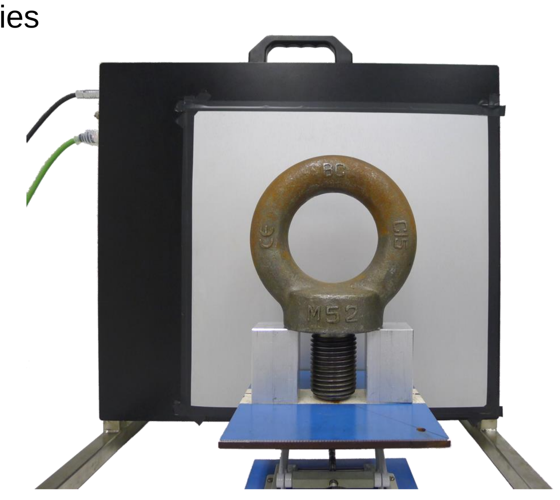


Fig. 8: Test samples (Al, Graphite, Fe, Pb, W, concrete, PE).

Summary

- First radiography with test samples successful, despite low detector efficiency and neutron intensity
- Discrimination between light and heavy objects
- Correlation between detector signal and absorption properties



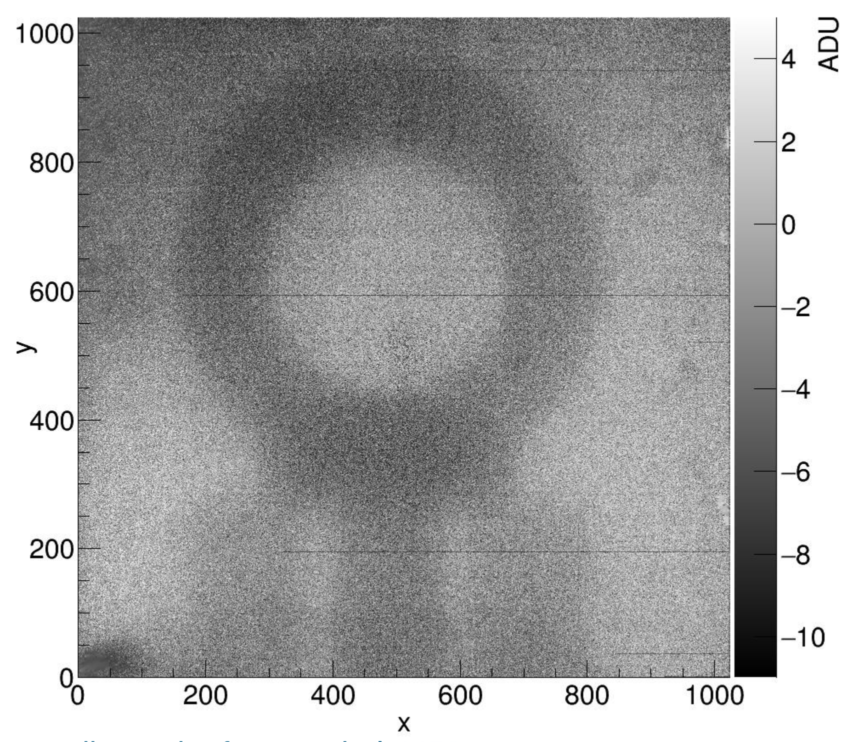
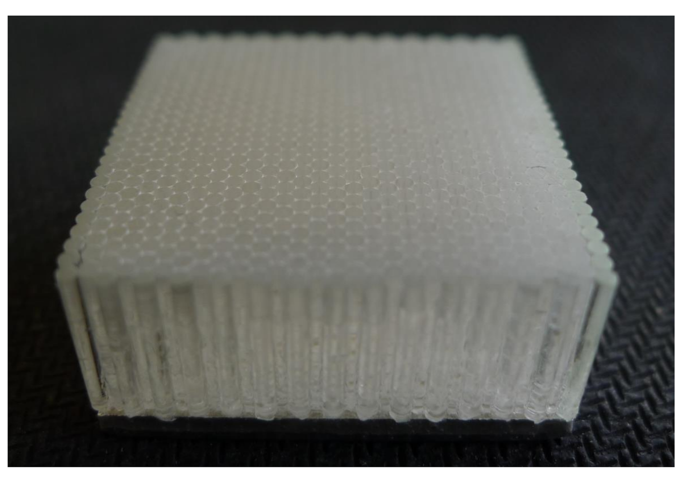


Fig. 10: Photograph of the experimental setup and corresponding radiograph of an eye bolt M52.

Outlook

New Scintillator

- Stack of scintillating fibres for increased neutron conversion efficiency
- Type: SCSF-3HF(1500)MJ from Kuraray
- Thickness: 10 mm, diameter: 1 mm



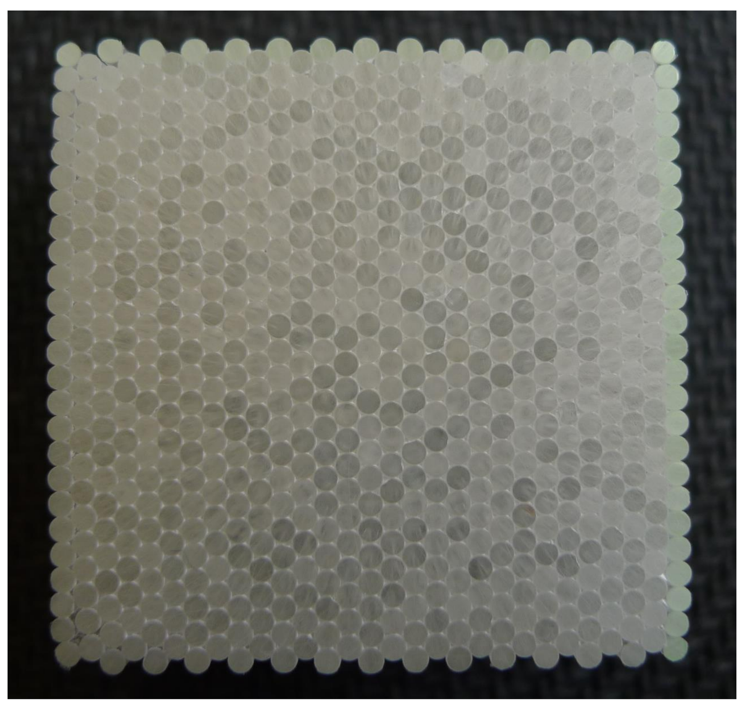
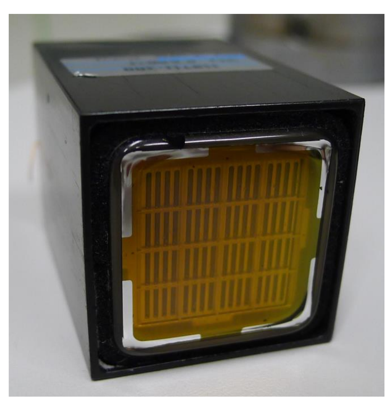
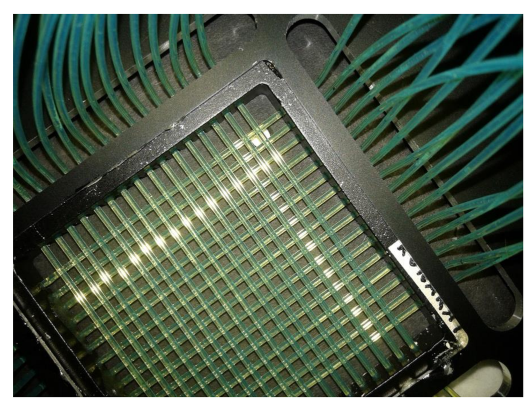


Fig. 11: First proof of concept for a scintillator as a stack made from scintillating fibres a) side view b) top down view.

Wavelength Shifting Fibres Detector

- Prototype detector
- Plastic with ZnS as scintillator
- X-Y crossed WLS fibres
- Fibre readout with PMT
- TDC coincidences for position reconstruction
- Active area: 4 x 4 cm² (16 x 16 fibres)

a) 

b) 

c) 

Fig. 12: a) Photomultiplier used for the detector. b) Close-up from the crossed fibres. c) Detector in light tight housing.

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